# Human-Computer Interaction in Distributed Supervisory Control Tasks

Final Report

Christine M. Mitchell
Principal Investigator

Center for Human-Machine Systems Research
School of Industrial & Systems Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332-0205
(404) 894-4321
cm@chmsr.gatech.edu
E24-633

Goddard Space Flight Center
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Walt Truszkowski, Technical Monitor

This grant was one of the more productive funded at the Georgia Institute of Technology's Center for Human-Machine Systems Research. It included the sponsorship for four Ph.D. theses and a variety of publications. The work spanned five years and its impact is far reaching. Appendix A lists the Ph.D. students whose research was supported in part by this grant. Appendix B lists the book chapters and refereed journal papers. In addition, there were dozens of conference papers describing the evolution of the various projects supported by this grant. Copies of these documents are available from the principal investigator.

The early portions of the work extended the original NASA Goddard GT-MSOCC research exploring the design of an on-line intent inferencer, OFMspert (Rubin et al., 1988; Jones et al., 1990; Mitchell, 1995) and its use as the intelligence for an active operator aid (Bushman, 1989). Bushman showed that an aid utilizing the intelligence of OFMspert cooperating with a controller resulted in performance comparable that between two human controllers (Bushman et al., 1994). Pawlowski (1990) extended the OFMspert and operator function model model-based design strategies to propose an interface design methodology that showed that 'good' display design in conjunction with an operator intent inferencer could perform as well as a the Bushman intent inferencer which operated with traditional (i.e., hard-to-use) displays.

The second half of the efforts supported by this grant comprised a major contribution to the methodological approach for conducting realistic, useful university-based research (Jones, Chu, and Mitchell, 1995). Both Jones' cooperative problem solving research (Jones, 1991) and Chu's architecture for intelligent tutoring for operators of complex dynamic systems (Chu, 1991) were implemented in a realistic real-time simulation that comprised a subset of essential satellite ground control functions. Moreover, the empirical validation was conducted with Goddard Space Flight Center operators. In addition to the substantive merits, both of these theses, with respect to methodological underpinnings, made an important contribution to the academic community regarding strategies and merits: proof-of-demonstration of how to move beyond laboratory tasks and naive subjects into the real world with its associated, but interesting, problems and skilled, but always surprising, problem solvers.

Chu's work turned out to be the research effort with which I am most pleased to have been associated in fourteen years of academic research. At the conclusion of her empirical evaluation conducted on-site at Goddard, operations management and personnel decided that her tutor was so effective that, with minor modifications, it would be immediately useful in day-to-day training of satellite ground control operations. To this day, it is an essential part of the Code 510 training program. Moreover, Chu's more general architecture has set a standard for the design of ITS architectures for training operators of complex dynamic systems and is being tailored for use in other domains in including pilots learning to fly highly automated cockpits and air traffic controllers.

## Appendix A

### Ph.D. Students Supported in Part by this Grant

James B. Bushman, Lt. Col., U.S. Air Force
Graduation: March 1989
Thesis: Identification of an Operator's Associate Model for Cooperative Supervisory Control Situations

Thomas J. Pawlowski, Lt. Col., U.S. Air Force
Graduation: December 1990
Thesis: Design of Operator Interfaces to Support Effective Supervisory Control and To Facilitate Intent Inferencing by a Computer-Based Operator's Associate

Patricia M. Jones
Graduation: Summer 1991
Thesis: Human-Computer Cooperative Problem Solving in Supervisory Control

Rose M. Chu
Graduation: December 1991
Thesis: The Tutor-Aid Paradigm: Design of Intelligent Tutoring Systems for Operators of Supervisory Control Systems

## Appendix B

### Journal Papers and Books Supported in Part by this Grant

**Books**

Mitchell, C. M. (1994). Human-machine system models: A prerequisite to the design of human-computer interaction in complex dynamic systems. In P. Polson (Ed.). *Human-computer interface design: Success cases, emerging methods, and real-world context.* in press.

Mitchell, C. M. (1995). Operator models, model-based displays, and intelligent aiding. In W. B. Rouse (ed.). *Human-technology interaction in complex systems.* Vol. 6, 233-293, Greenwich, Connecticut: JAI Press Inc.

**Journal Papers**

Rubin, K. S., Jones, P. M., and Mitchell, C. M. (1988). OFMspert: Inference of operator intentions in supervisory control using a blackboard architecture. *IEEE Transactions Systems, Man and Cybernetics.* 18(4), 618-637.

Jones, P. M., Rubin, K. S., and Mitchell, C. M. (1990). Validation of intent inferencing by a model-based operator's associate. *International Journal of Man-Machine Studies.* 33, 177-202.

Mitchell, C. M. and Govindaraj, T. (1991). Design and effectiveness of intelligent tutors for operators of complex dynamic systems: A tutor implementation for satellite system operators. *Interactive Learning Environments.* 1(3), 193-229.

Bushman, J. B., Mitchell, C. M. Jones, P. M. and Rubin, K. S. (1993). ALLY: An operator's associate for cooperative supervisory control. *IEEE Transactions on Systems, Man and Cybernetics.* 23(1), 111-128.

Jones, P. M. and Mitchell, C. M. (1994). Model-based communicative acts: Human-computer collaboration in supervisory control. *International Journal of Man-Machine Systems.* in press.

Jones, P. M., Chu, R. C. and Mitchell, C. M. (1995). A methodology for human-machine systems research: Knowledge engineering, modeling, and simulation. *IEEE Transactions on Systems, Man and Cybernetics*, 25(7) July 1995, to appear.

Jones, P. M. and Mitchell, C. M. (1995). Human-computer cooperative problem solving: Theory, design, and evaluation of an intelligent associate system. *IEEE Transactions on Systems, Man and Cybernetics*, 25(7)July 1995, to appear.

Chu, R. W. and Mitchell, C. M., and Jones, P. M. (1995). Using the operator function model/OFMspert as the basis for an intelligent tutoring system: Towards a tutor-aid paradigm for operators of supervisory control systems. *IEEE Transactions on Systems, Man and Cybernetics*, 25(7) July 1995, to appear.